Mineral policy for industrial rocks and minerals

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INTRODUCTION

When geological material is found, identified and quantified, questions arise about its value and usefulness. For many years natural rocks and minerals have served us in our daily lives and the amounts used and their applications grow continuously. However, in the beginning, the decision about what to do with the material is complex and it is mater of optimisation. The objective of this paper is to show some important aspects in the formulation of a healthy mineral policy, which comprises of the application of the most modern achievement of science, technology, economy measures and at the same time, respecting cleanness of the environment. Prerequisite of proper valuation of resources are comprehensive characterization and categorization of deposits. These usually need more time than expected because of the guarantee of quality for a long supply period. Industrial rocks and minerals are multifunctional, being used for several purposes. Different grades are produced and specific quality requirements formulated. Finally, in an overview lecture, citation of each detail would expand and complicate the compiled text. Therefore, the main sourcebooks are listed as 'suggestions for further reading'.

INDUSTRIAL MINERALS IN OUR DAILY LIFE

The use of industrial rocks and minerals impacts virtually all aspects of our lives. This is true for both the direct and indirect use of rocks and minerals. Direct use utilizes the actual mass of these materials. The materials can be applied in their original, raw form or can be modified and processed. In this latter application the rocks and minerals are transformed into manufactured products in which the original form is often not recognizable. Indirect use of industrial rocks and minerals utilizes the properties and services of these materials.

THE INTEGRATED SYSTEM OF NATURAL RAW MATERIALS

Historically, natural raw materials were subdivided in three groups: metallic materials (ores), non-metallic materials and fuels while the others, life supporting raw materials such as soil, water, air, were not considered as raw materials and were not incorporated in the system. Due to the increased contamination of soils, water and air, these basic materials became a focus of many mineral policies. Technological and industrial development generates growing interest and a continuously expanding supply of conventional and afore mentioned neglected raw materials. Modern technology developed new materials with properties that could not be solely produced from one raw material. The development of artificial composite materials such as cermets and multi-layers followed. Such materials integrate and exhibit exceptional properties of each component.

Also the services of some raw materials are unavoidable. For instance, reaching low temperatures would be impossible without noble gasses. Moreover, some ores and metals (e.g. samarium, cobalt, hematite, pyrolusite, chromite and others) are being used as industrial minerals and *vice versa*, some industrial minerals act as ores (e.g. alunite, clays, beryl and others.). Therefore the proposed system of raw materials should comprise all natural materials including biota (living organisms) and organic matter (e.g. wood, animal hair). Additional artificial materials (plastics) are also considered (as products from fuels) because of their progressively growing involvement in composites. The integrated system (Table 1) reflects the new concept of material science, that considers all raw materials in theirs mutual interrelation.

There are more than 100 industrial rocks and minerals. Table 2 shows only the most common ones and will be modified in the future. While some minerals are listed as distinct mineral phases, others are listed as groups (e.g. Ba-minerals, Feldspars, Garnets). For rocks are used petrological names and historically introduced group names 'granites' (for hard

TABLE 1.
INTEGRATED SYSTEM OF RAW MATERIALS

BASICS	**ORES**	**FUELS**	**IND.MINERALS**
Life support	***Winning of metals***	***Energy Generation***	***Industrial applications***
AIR NOBLE GASSES WATER MIN.WATER ICE SOIL	HIGH GRADE LOW GRADE IND.VASTE GARBAGE ALTERNATIVES (clay, gypsum, alunite)	GAS OIL COAL OIL SHALE METALS (Al) SULPHUR HYDROGENE	ROCKS CRYSTALS MINERALS MIXES COMPOSITES (natural & synthetic)

ORG.MATTER
BIOTA

PLASTICS

TABLE 2.
INDUSTRIAL ROCKS AND MINERALS

ANTIMONY	ASBESTOS	ATTAPULGITE
Ba-MINERALS	BAUXITE *)	BENTONITE
Be-MINERALS *)	BORATES *)	BROMINE *)
CALCITE & LST.	CHROMITE	CORUNDUM *)
DIAMOND *)	DIATOMITE	DOLOMITE
FELDSPARS	FLUORSPAR	GARNET *)
GLAUCONITE	'GRANITES'	GRAPHITE *)
GYPSUM& anhydrite*)	IODINE *)	IRON OXIDES *)
KAOLIN & clay mins*)	Li-MINERALS	MAGNESITE *)
'MARBLES'	Mn-MINERALS *)	MICAS
MONAZITE	NEPHELINE (syenite)	N-COMPOUNDS *)
OLIVINE	PERLITE	PHOSPHATES *)
POTASH *)	PUMICE & SCORIA	PYROPHYLLITE
REE-MINERALS	SALT *)	SAND & GRAVEL
SEPIOLITE	SILICA & QUARTZ *) Incl. tripoli and flint	SILLIMANITE, Al-silicates, mullite *)
SODA & soda ash*)	SODIUM SULPHATE	STAUROLITE
Sr-MINERALS	SULPHUR *)	TALC
Ti-MINERALS *)	VERMICULITE	WOLLASTONITE *)
XENOTIME	ZEOLITES *)	Zr,Th-MINERALS
CRYOLITE *)°)	HYDROTALCITES**) Layer double hydroxides	METALS**) (e.g. Co,Cu)

*) Also synthetic **) Only synthetic °) Nearly exhausted natural resources.

rocks) and 'marbles' (soft rocks). Both simplified terms of industrial rocks include rocks in all forms as dimension blocks, crushed aggregate, milled products and others applied as construction materials.

From the discovery of a deposit of any useful raw material to the manufacturing of products is a long and not always a straight forward way. The exploration geologist initiates an action that is followed by other specialists who assess the usefulness of the product, investigate mining and processing procedures, develop manufacturing technologies, and address the economical and the environmental aspects. An important document made prior to exploitation and manufacturing of products is called feasibility study. The objective of the whole operation is the optimum utilization of the raw material by technological procedures with minimal waste and damage to the environment.

That goal can be reached faster when a healthy **mineral policy** is formulated in advance, with everything in its correct which all involved specialists supply the appropriate information and suggest a course of actions in the right sequence. For that we use a project, a plan of operations, that summarizes the basic principles and routines of applied disciplines. Lack of a good mineral policy usually results in an unsuccessful operation. The main shortcomings of mineral policy are: (1) lack of knowledge of political and economical constraints that may impair the exploitation of raw materials, (2) lack of knowledge of the usefulness of raw materials in a variety of industries, (3) lack of knowledge of quality requirements for particular product, (4) lack of knowledge of the market development and competition and (5) insufficient consideration of the environmental impact. Avoiding project failure requires a multidisciplinary approach, including geological sciences, mineral economy and mineral technology and legislature regarding the protection of the environment.

Another problem, that is specific for the exploration geologist, is the lack of understanding of the scale of operation with all its consequences. Comprehensive raw material characterisation should deal with representative bulk samples of a certain size, appropriate to the scale of operation. Small and usually upgraded samples can indicate only an isolated mineralogical occurrence and are less useful for industrial application.

Nowadays, widely developed analytical techniques offer a variety of methods for analysis and testing of materials. One can spend months to analysing and testing one raw material. In the vast array of procedures and methods it is necessary to select the simplest and the most sensitive set of techniques that lead to the proper diagnosis of the raw material. An analytical strategy has to be designed in order to save time and money. The analytical strategy will depend on the quality requirements, the supplied raw material should meet for a particular application.

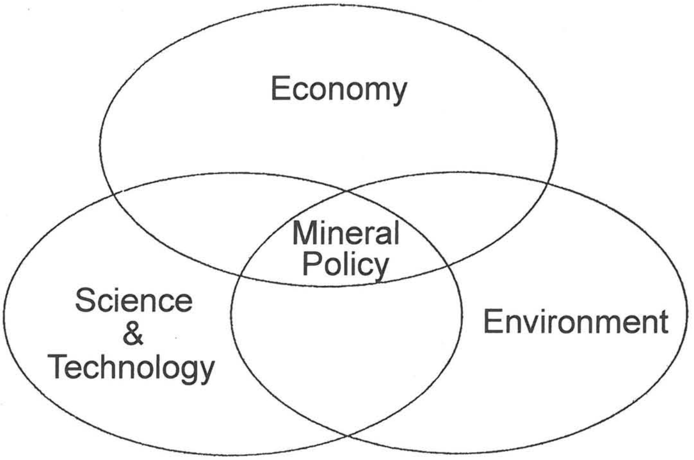

FIGURE 1. *Principles of formulation of mineral policy as a compromise. Modified after Kühnel (1990).*

- **Mineral policy summarizes WHAT?, WHY?, WHERE?, WHEN?, and HOW? Certain raw material will be exploited, treated, utilized or exported.**
- **Three major aspects to be considered for its formulation: (1) ECONOMY, (2) SCIENCE AND TECHNOLOGY AND (3) ENVIRONMENT.**
- A healthy mineral policy compromises of EFFICIENCY, technological FEASIBILITY and environmental and health SAFETY.

  Only when agreement is reached between these three aspects, is the mineral policy acceptable and healthy. Mineral policy is designed to optimize the use of a mineral resource in a certain region or country. It comprises of principles and rules on how to efficiently manage the exploitation of material for sale and/or for the manufacturing of products. There are two scenarios for the formulation of mineral policy: The first is applied, when raw material is needed for an already existing industry. In such a case, only a small fraction of suitable materials is the focus. Reserves are rather limited and after their selective extraction, large bulks of unsorted rejects remain. The second scenario begins with comprehensive material characterization and evaluation of the optimum use of the material. The objective of a mineral policy is the utilization of the most profitable fraction and subsequent recovering of **valuable by-products** from the properly stored rejects.

SOME ECONOMICAL ASPECTS

(1) In dealing with deposits of industrial rocks and minerals, the following questions to be answered:

- What is the product worth?
- How much will it cost to get production started?
- How much time is needed to start production?
- What are the risks?
- When will the capital be recovered?
- What environmental impact will the operation have and what consequences are to be expected?

(2) Categorising industrial rocks and minerals into several categories is a useful precursor to undertaking a technical and economic evaluation of the potential resources. An example of four categories of industrial clay resources (C. Harvey 2002) is shown in Tables 3 and 4. The exploration and evaluation of deposits of different categories proceeds in steps. According to the size of a deposit it requires more or less time to the final decision to invest. The categorization benefits the explorer or developer as it assists in estimation of (1) a development strategy, (2) time to move from planning to production and (3) work and provisional cost. The Manual of UN Industrial Development (1978) can also be of great assistance in the project which deals with the preparation of the Industrial Feasibility Studies.

(3) Factors affecting the price of raw materials.

- **Rarity** of the mineral: for example hectorite is rare, therefore expensive whereas other clays are relatively cheaper.

TABLE 3.
EXAMPLE OF CATEGORIZATION OF CLAY DEPOSITS

CATEGORY	Features
1. **100-300kt/y**	• High quality • High technology • Requiring major investment for large tonnage production • Supply local and international market
2. **10-25kt/y**	• Unique and special clays • Advanced technologies • Small tonnage market locally and internationally • Unusual, high value, typically high purity deposits • Unique geological conditions
3. **market dependent**	• Moderate quality clays • Include lower technology • Mainly for local market
4. **market dependent**	• Clays of variable quality (heterogeneous) • Presence of impurities • Limited low cost market • Justifying little or no processing • Large tonnage local markets Clays of the 4th category even of moderate to high quality are considered non-economic because of isolation from markets, politically or economically unstable locations or unfavourable legislative environment.

- **Quality** of the raw mineral or product: significantly higher prices are paid for even a small increase in purity or concentration; for example the price of high kaolinite content clay (>95% kaolinite) is higher than the price of china clay with 80-90% kaolinite. An important parameter of quality is minimum fluctuation of composition and properties, in other words **the quality assurance**.
- **Mining costs:** some minerals are easily mined whereas others occur in areas demanding high costs; e.g. due to underground mining, stripping of thick overburden, selective mining, consistency, and blending. These operations call for more labour and more analyses and testing
- **Processing costs** and 'added value': for example the price of extremely fine kaolinite for pharmaceuticals is several times higher than china clay for ceramics. Applied upgrading technology and associated higher energy input during mineral processing are the main reasons for the increase in price

TABLE 4.
STAGES OF ACTIVITIES AND INVESTMENT

Activity Category	**1**	**2**	**3**	**4**
STAGE 1: RECONNAISSANCE				
Geological reconnaissance, property survey, Testing, broad categorisation of materials, Market surveys and evaluation				
Decision to proceed	12 months	9 months	6 months	3 months
STAGE 2: EXPLORATION (Pre-feasibility)				
Property negotiation, drilling, testing, market surveys, material characterisation, process flow sheet development, resource calculations, economic studies and evaluation				
Pre-feasibility study and decision to proceed	18-24 m	9 months	9 months	6 months
STAGE 3: DELINEATION & FEASIBILITY				
Drilling and detail testing, market surveys and negotiation, bulk samples, engineering studies, assessment of products in the marketplace, economic studies and evaluation				
Feasibility study	24 months	12 months	9 months	3 months
STAGE 4: DECISION TO INVEST				
Total time since project initiation	4-5 years	2-2½ years	2 years	1 year
Design, construction and commissioning	1-2 years	1 year	1 year	1 year
Typical overall project time	**5-7 years**	**3-4 years**	**2-3 years**	**1 year**

MARKETING (Introduction of new raw material to the market)

- Even with strengths, the new supplier in the market has to expect conservatism. The rate of products may be partly good fortune or even luck. For some products it may take years to gain full market acceptance
- User industries are often conservative by nature. Do not readily accept new products. The first stage is to convince a company to trial new product. It may be possible on the basis of higher quality and homogeneity, lower price, better continuity and advanced technical support.
- For reducing risk and for shortening project time (for categories 1 and 2) associate with, or form a joint venture with already established producers in the industry
- Associate with or form a joint venture with major market users of the product
- Engage specialists consultants for resource evaluation, marker surveys and engineering
- Develop resources adjacent to proven (identified) resources already established in the
- market place

- **Transport and handling costs:** e.g. bagged or packed minerals (protected against contamination) are usually more expensive than bulk materials, examples being different high grade clays. The active radius of transport is controlled by the value of the product. Tailored mixes 'ready to use' are usually packed and usually more expensive than self made mixes.

PRICES OF INDUSTRIAL MINERALS AND ROCKS

The price of raw material is a variable. It is controlled by the market, quality, offer and demand and by other factors. Therefore, prices change continuously. A new application of a raw material will drive the demand up and increase its price The market is volatile and reacts sensitively to any changes of quality requirements. The upgrading process always causes a price increase. The price difference must be justified. It should cover the costs associated with the alteration of the extraction procedure (e.g. selective mining), processing and reflect changes of reserves. Prices of industrial rocks and minerals vary greatly from few US $ to more than one million per ton. The following table lists price categories (in US$/t) of some industrial minerals and rocks.

<10 USD	crushed rock, limestone, sand & gravel, clay, gypsum, salt, anhydrite, soil, fly ash, recycled concrete
10-100	barite, bentonite, chromite, dolomite, feldspar, flint clay, fluorite, ilmenite, kaolin, monazite, nepheline, phosphates, syenite, pumice, salt,
100-1000	bentonite, borax, diatomite, graphite, kaolin, palygorskite, perlite, REE-minerals, sulphur, talc, wollastonite, xenotime, zeolites, zircon
1000-10,000	bastnasite, bromine, graphite, REE oxides, rutile, silicon carbide
>10,000 USD	diamonds, iodine, REE oxides

Some commodities are mentioned in two price categories because of different grades. Prices also change when resources become exhausted or new resources are found.

MULTIFUNCTIONAL MATERIALS AND FUNCTIONAL GROUPS

The majority of industrial rocks and minerals are multifunctional that is to say: the same rock or mineral is used for different purposes. An excellent overview of the applications are in the book of Harben (1995) Quartz has the longest history of multifunctional uses. In prehistoric times it was used for making fire and the manufacturing of arrowheads, knives and primitive tools, weapons and jewels. Quartz applications are documented on hundreds of artefacts collected and exhibited in museums of human history around the world. At present, quartz is a leading industrial mineral in modern technology being involved with applications in energy generation (silicon wafers for solar energy), in the manufacture of electronic devices (chips and piezoelectric and electrooptic ceramics), and the manufacturing of glass fibres for communication. Another important application includes silicon carbide (future material for car engines), silicites and silicon alloys and many others.

Also, some industrial rocks are multifunctional. Table 5 shows example of multifunctionality of basaltoids. Basaltoids (basalt-like rocks) serve traditionally as common material for the construction of buildings, roads, water works (as aggregate). Newer products from basalt and related rocks include rock wool (sound and thermal insulators) and molten basalt lining of pipelines and trenches against abrasion. Ground and milled basalt is commonly used as an agricultural mineral for soil structure improvement and soil fertilizing because of its high nutrient content. One application of basalt powder is in air filters and also in special ceramics.

Industrial rocks and minerals can be also classified according their function in the processes of application as shown in Table 6. Functions result from distinct properties. For example, hard materials having angular particles are used as materials for cutting, grinding and polishing softer materials. A variety of industrial rocks and minerals with suitable hardness and angularity of particles are used as abrasives. Therefore, diamond, corundum, quartz, spinel, garnet, wollastonite, even crushed slag or hard rocks are mentioned in the functional group 'Abrasives'. Abrasives are sold as crystals, sintered bodies, powders, paste or sprays. Obviously, there are qualitative differences that are reflected in the prices. Several million tons of abrasives are consumed worldwide yearly.

Other functional groups list industrial minerals commonly applied for manufacturing certain products. For example raw materials frequently used for manufacture of low- to high refractory materials, belong to the functional group of 'Refractories' due to their distinct thermal resistance. The range of refractory materials changes intensely from kaolinite, halloysite, dolomite, magnesite, chromite, periclase, mullite, α-alumina, silicon carbide, BeO and ThO_2.

MATERIAL CHARACTERIZATION *(Figure 2)*

The main objective of scientific and technological appraisal of raw material is the determination of its value and optimum application. The value of a raw material and its optimum use are recognized only by means of a thorough characterization. Characterization is performed with different weights and levels. A general scheme of characterization is shown in Figure 2 as a pyramid with three levels subdivided into six sub-levels.

The first level comprises of qualitative and quantitative data on chemical and phase (mineral) composition and fabrics. These parameters predetermine the physical and chemical properties considered as isotropic (scalars) or anisotropic (vectors). The behaviour of the material is the highest dimension of characterization that characterizes changes of a material and its properties in time and/or under fluctuating conditions. For material characterization, there are numerous analytical techniques and testing procedures. Nevertheless, for specific use, only a selection of these is applied. Each application of industrial rock and minerals calls for an efficient analytical strategy that supplies crucial diagnostics of the target raw material.

The comprehensive characterization of composition comprises of major and minor elements and major and accessory minerals as well. Partition of elements in coexisting phases and spatial distribution of mineral phases is crucial for eventual treatment and processing. Fabrics of material (structural and textural features and 3D orientation of constituents) should be also quantified.

TABLE 5.
UTILIZATION OF BASALTOIDS (BASALT, BASANITE, DOLERITES...)

Use	Required properties
Ground & milled basaltoid Fertiliser Correction of soil Fillers	Solubility Alkali metals and earths Iron and magnesium content Phosphorus content No hazardous elements Particle size Clay mineral content Particle size Porosity Sorption/desorption
Melted & sintered basalt Lining slabs for trenches, Cyclones, etc. Lining of pipes Ceramics Granules Artistic objects	Melting temperature Viscosity Low thermal expansion and shrinkage Re-crystallisation Sintering temperature Resistance against abrasion
Construction materials (roads, water works, monuments, etc.) Aggregate Blocks Cubes Decorative stone (furniture, open hearths) Granules Macadam Monumental stone Reinforcement of dikes, piers, wharfs and dams Slabs Tiles Tombstone	Abrasivity Appearance Colour Composition (mineralogical an chemical) Deleterious materials (fines and impurities) Density & hardness Durability Reactivity Size and shape Solubility Soundness Strength and toughness Water uptake/Porosity Workability
Insulators Rockwool Packing material (for dropping from airplane) Substrate (for plants and flowers)	Low melting point Low eutectic Viscosity 25-30 poise Size of fragments Equigranular texture 35-50 SiO_2, 15-40 CaO 10 MgO, 10-15 Al_2O_3 Low volatiles (Cl, F, H_2O) Toughness and elasticity Non-inflammable Low thermal conductivity Sound insulation No hazardous elements

TABLE 6.
FUNCTIONAL GROUPS OF INDUSTRIAL ROCKS AND MINERALS

Abrasives	**Ceramics**	**Fertilizers**
quartz corundum garnet diamond wollastonite slagg staurolite tripoli Fe-oxide	ball & plastic clays kaolinite & halloysite quartz & silica sand feldspars & nepheline common clay pyrophylite talc wollastonite zircon	nitrates phosphates feldspars carbonates gypsum bentonites zeolites basaltic rocks
Fillers	**Fluxes**	**Foundry minerals**
kaolinite illite halloysite limestone baryte talc chlorite quartz	apatite borates Li-minerals limestone feldspars nepheline fluorite soda ash	quartz olivine zircon graphite bentonite coal perlite pyrophyllite
Insulators	**Pigments**	**Refractories**
asbestos bentonite diatomite vermiculite rockwool expanded shale perlite tobermorite	kaolinite Ti-minerals limestone iron oxides glauconite celadonite umber bentonite chlorite schist	kaolinite halloysite quartz alumina dolomite magnesite chromite mullite silicon carbide

Physical and chemical properties are determined for particular constituents and the bulk as well. Properties of material result from elemental and phase compositions and fabrics. In time, or under different conditions of exposure, the composition of the material and its properties may change. This is called behaviour. The short- or long-term changes are determined by the reactivity of the material.

RAW MATERIAL GRADES *(QUALITY CLASSES)*

Raw material characterization allows a decision to be made on optimum use. Raw material should meet criteria dictated by the user or manufacturer, asking for a certain specific grade. The term **grade** expresses the quality of a raw material in considering the amount of target minerals and specific properties. First, the supplier specifies the offered material, but the user and manufacturer may ask for corrections of certain parameters. The final grade definition is dependent on mutual agreement. Grades are often called according to their major applications:

I. Examples of grades specified by chemical composition and/or mineral composition:
(only the most critical parameters are listed)

CHROMITE: three major grades are specified: metallurgical, chemical and refractory grades according to the Cr, Fe, Al and Mg content.
Mn-MINERALS: metallurgical, chemical and battery grades,
specified by Mn-content and limits of impurities contents (elements and/or minerals)
LIMESTONE: calcium carbide grade
97% ($CaCO_3$ incl. max 2%$MgCO_3$), max 3% SiO_2, max. 0,002% P
QUARTZ SAND: optical glass grade
99.5% SiO_2, 0,1-0,5% Al_2O_3, 0.030% Fe_2O_3, particle size 0,1-0.5 mm
max. 6 ppm Cr, max. 2 ppm Co, and 0,01-0.05% TiO_2

II. Examples of grades specified by crucial properties quantified by minimum/maximum values or by ranges. Usually it is a prescribed procedure on how the property should be measured.

KAOLIN: paper grade; brightness 87,5±0.7
CLAY: refractory clay grade: Refractoriness 1750-1770°C (EU)
BENTONITE: drilling mud grade is specified by apparent viscosity (15-16 centipoises) and max. yield point/plastic viscosity ratio (15-16)
PERLITE: expanding grade requires an expansion temperature range 760-1,000°C and expansion ratio –20

The QR of the majority of industrial minerals are specified by both composition and properties. QR are arbitrary, and, from time to time may be changed when alteration of the technology takes place. The listed main grades of the kaolinite demonstrate differences:
Filler grade kaolinite should contain >90% kaolinite, 1% Fe_3O_3 + TiO_2, 1-2% low abrasive quartz, brightness >80%, 50-70% particles -2μm and Brookfield viscosity <4,000 cpe.
Coating grade kaolinite should contain 90-100% kaolinite, 0.5-1.8 Fe_2O_3, 0.4-1.6% TiO_2, no abrasive quartz, brightness >85%, 80-100% -2μm particle size and Brookfield viscosity <7,000 cpe
Ceramic grade kaolinite should have 75-85% kaolinite, defined amounts of minerals affecting colours, viscosity and abrasiveness. In addition, for bone china and porcelain is requested a fired brightness 83-91% after firing to 1,180°C, strength and other properties.
Refractory grade kaolinite-bearing clays should resist temperatures of 1,500°C. Depending on Al_2O_3, Fe_2O_3 and alkali metals content, low-, moderate- and high-duty grade are distinguished.
Fibreglass grade kaolinite is used as source of silica and alumina. Typical re 37% Al_2O_3 and 44% SiO2, 1% Fe_2O_3, about 2% Na_2O and 1%H_2O

Cosmetic grade kaolinite should have <2ppm of arsenic, <20ppm heavy metals, <350ppm of chlorides, <15% loss of ignition and pH of suspension 7.5±0.5

QUALITY REQUIREMENTS (QR)

QR is a sum of material features and technological conditions that guarantee a successful manufacturing of the product

QR specify:

(1) Chemical and mineral compositions, fabrics and physical and chemical properties of all present minerals (with an emphasis on impurities and hazardous constituents)
(2) Preparation (treatment and/or processing) procedures of material for the manufacturing process
(3) Analytical and testing techniques for all materials, half- and final products
(4) Possible environmental impact

Quality requirements are universal for a particular raw material and/or for its grade, while others are specific for certain products and/or technologies. The users usually specify these requirements. Chemical composition focuses on major and minor (trace) elements of interest, and on hazardous elements. Mineral- (preferably phase-) composition also specifies essential and minor constituents of interest, their particle size distribution and mode of occurrences. In focus are the minima of useful constituents, and maxima of tolerable and non-tolerable impurities. From the point of view of technology, QR require ranges of physical and chemical properties of particular constituents and behaviour of bulk raw material.

The most common reason of the amount of rejected products is associated with the fluctuation raw material quality. Maintained constant quality of raw material (homogeneous feed of the plant) is the major prerequisite of any successful manufacturing. Differences are caused by periodical supplies and also by improper handling and stockpiling. Quality changes in time, hours, days, month and years and that affects the final quality of the product. One solution of the problem is in the utilization of a programmed stockpile for a longer period. In this way, the short-term fluctuations of the composition of fed raw materials into a plant are evened out. Proper blending and mixing of raw materials help to achieve the homogeneous feed. It is desirable to prepare a stockpile of raw materials for longer periods, between one month and one year, depending on the amounts supplied and the raw material heterogeneity. A second solution is in the utilization of "ready to use" mixes prepared in bags with a guarantee of a high level of homogeneity for the optimum mode of manufacturing.

Industrial minerals do not always occur in a form suitable for direct utilisation. Besides impurities, industrial minerals may have unacceptable features. Such lower grades may be subjected to processing (concentration, upgrading, beneficiation) or they can be temporarily rejected and stored for later, when improved technology will be able to recover the valuable fraction. Conventional dry and wet procedures based on differences of physical and chemical properties such as density, magnetic, electric properties, solubility, surface reactivity and others are used for separation of impurities and concentration of target minerals. But the

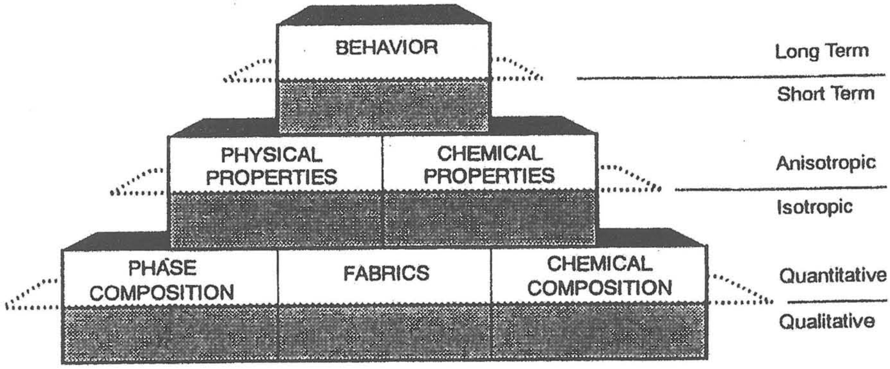

FIGURE 2. *Principles of material characterization (Pyramid of knowledge on materials). Modified after Kühnel (1990).*

major constraint of separation and concentration is the complete liberation from associated sterile minerals

With time, QR have been redefined many times. To the QR, new criteria are usually added, so that they became more complex and difficult to fulfil. Also the analytical and testing procedure for the determination of new properties became more complex. Consequently, the resources of certain grades become greatly reduced. In the future, QR should be justified and significantly simplified.

The definition of quality requirement, mentioned above, has been also conceptually redefined. Quality assurance became a new dimension. Nowadays, instead of a rather defensive function, quality assurance developed into a strategy and therefore has to be considered as a management function used offensively and successfully, as the market requires. In the new economic situation and due to the increasingly competitive, worldwide market, the new understanding of quality assurance is prerequisite of successful ventures.

In the past, quality assurance mainly concerned the control of either particular raw materials or a single process or a product. At present, the integrated concept is market-, customer-, technology- and production- oriented.

Examples of requirements for a quality assurance system for refractories, can be found in the German DIN ISO 9000-9004 which contains apart the management responsibility, the quality elements of contract review, design control, development, document control, purchasing, product identification and trace ability, process control, inspection and testing, corrective action etc.

ENVIRONMENTAL CONCERN

Environmental pollution is the result of human growth. All industrial activities generate local increase of contamination of soil, water and air. In addition, pollutants such noise, light or electromagnetic rays have to be considered. Through depositories of waste, artificial geochemical anomalies are formed. Around industrial plants, a serious increase of environmental damage occurs, associated with discharged water and emissions and scattered or deposited garbage and industrial waste as well. In time, natural processes are able to disperse the newly formed anomalies and remedy the situation in the affected areas. However, certain consequences of anthropogenic impact remain hazardous for a long time. The intensity of human activity has started to overburden the natural cleanup ability of mother nature.

Environmental science defines hazardous compounds, allowed limits of occurrences, principles of exploration of contaminated areas and rules of handling, recycling and storage of hazardous materials. Nowadays, the environmental impact is deeply integrated in the development of mineral policy and industrial development dealing with primary, natural, and, secondary, (recycled) materials

Complete prevention of environmental damage is impossible. However, it is necessary to reduce it to its utmost minimum. Over the years, mineral policies become stricter and it is often the older abandoned mining or plant operation that are featured in the news as hazardous. Intense environmental damage is associated with existing and historical industrial centres and plants. The remedy of the contaminated areas is costly and therefore all actions should be premeditated and justified.

THE FUTURE OF INDUSTRIAL MINERALS AND ROCKS

Regarding the growing population, expanding production and trends of technological innovation allow us to predict growing interest in industrial minerals and rocks. The formulation or refining of mineral policies is not an option but a necessity. Inventory of natural resources, import and consumption is the first task for all countries. Together with the characterization of particular raw materials, the registration of users and products may serve for the monitoring of efficient use, and safety.

In the future, the expanded use of recycled materials and higher involvement of purer synthetic materials with extraordinary properties is expected. The application of industrial minerals will grow with the designing of new composites of industrial minerals and/or combination with metals and organic materials. The leading position will have an application in energy generation and energy conservation, catalysis and electronic devises for communication and manufacturing of high-tech products.

Finally, the mineral policy for industrial rocks and minerals will be better functional when economist, scientist, engineer and environmentalist will mutually share not only the responsibility but also knowledge of their theoretical backgrounds.

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